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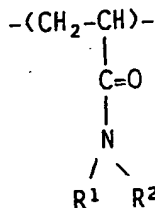
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## (54) Solid polyacrylamide electrolyte

(57) An ionically conducting solid polymer electrolyte is a complex of a homopolymerised or copolymerised N,N-disubstituted acrylamide with an alkali metal salt say lithium perchlorate. The acrylamide polymer units have the formula



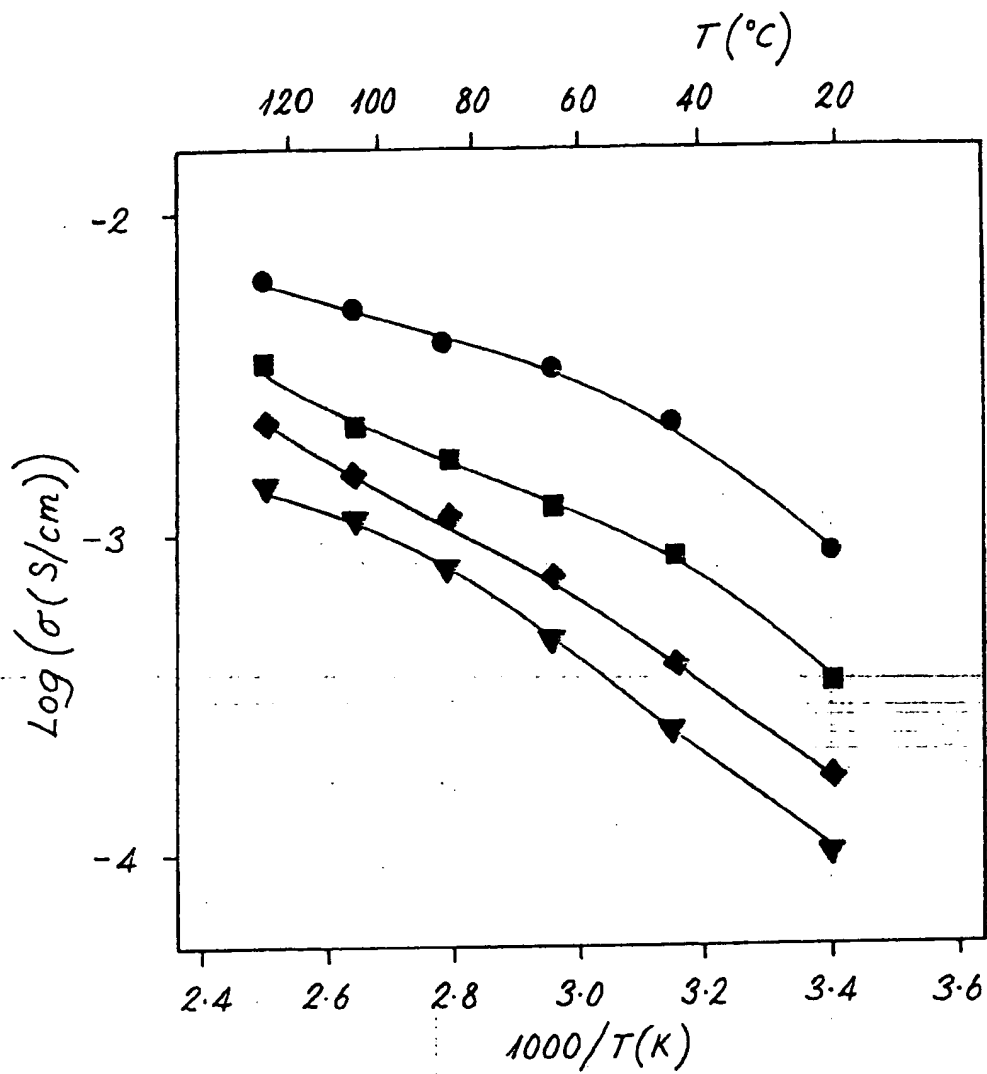
R<sup>1</sup> and R<sup>2</sup> may vary widely, and are e.g. methyl, or R<sup>1</sup>-N-R<sup>2</sup> may form a ring.

The complex is formed by dissolution of the acrylamide polymer and salt in a solvent followed by evaporation of the solvent, or by polymerisation of the acrylamide monomer in the presence of the salt and optionally a co-solvent, e.g. N,N-dimethylacetamide, which can act as plasticizer.

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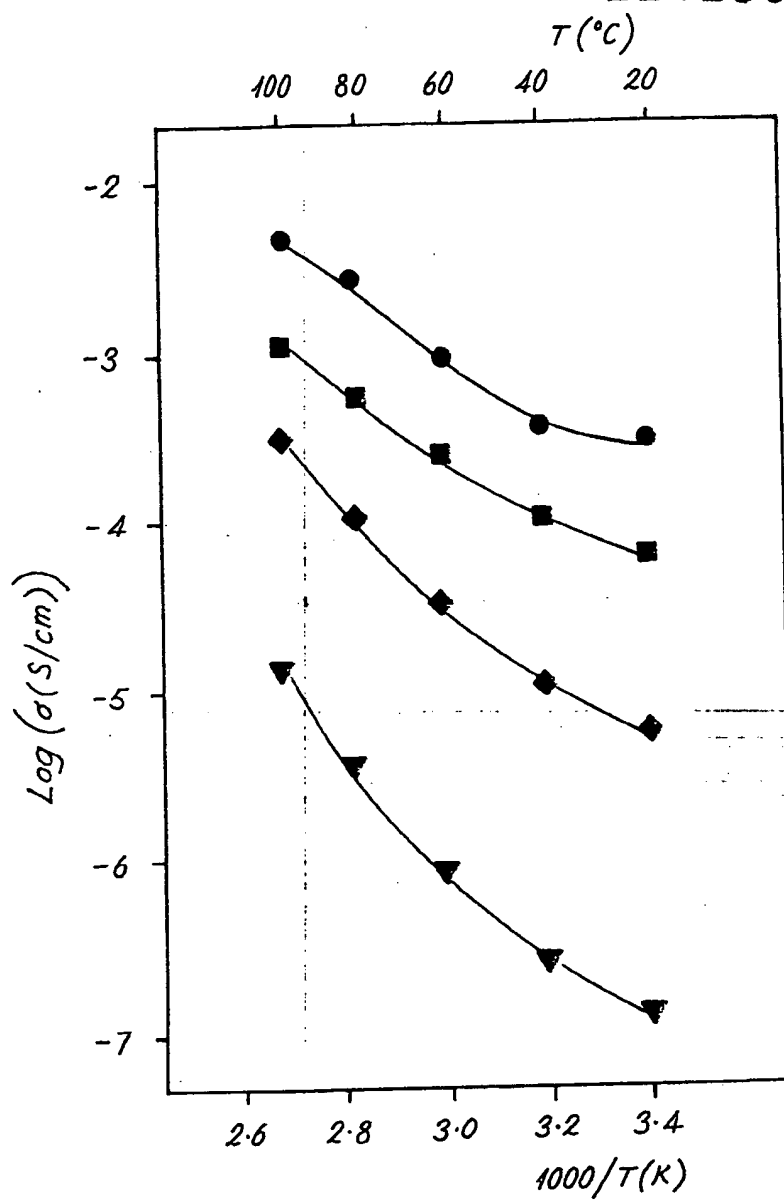


- monomer 40/60 plasticizer
- " 50/50 "
- ◆ " 60/40 "
- ▼ " 70/30 "

Fig. 1

2/4

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- monomer 40/60 plasticizer
- " 50/50 "
- ◆ " 60/40 "
- ▼ " 70/30

Fig. 2

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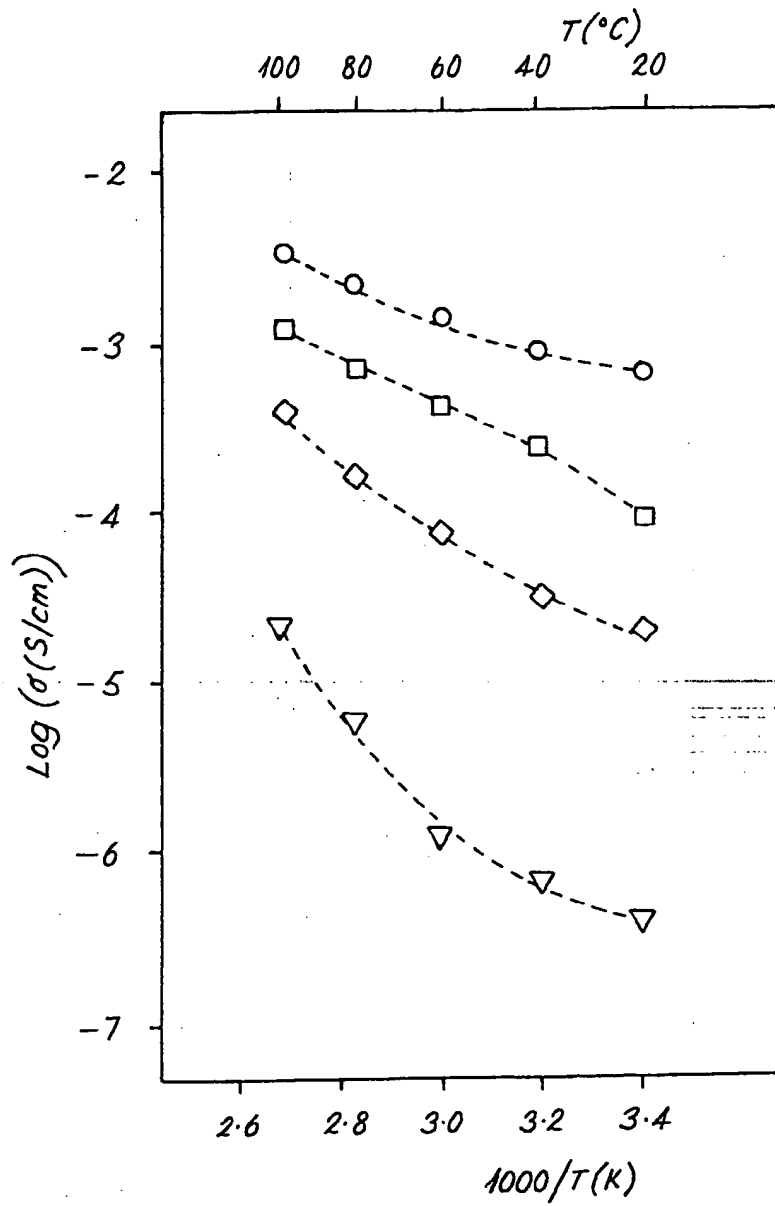
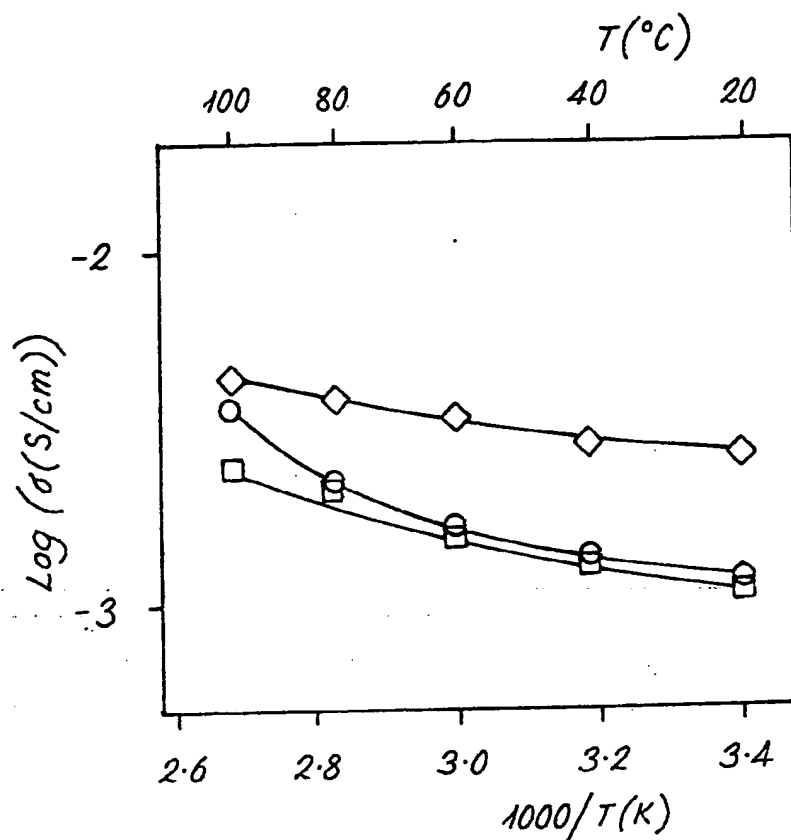


Fig. 3

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○ monomer 40/60 plasticizer 10% % X-linking monomer  
 □ " 30/70 " 20% "  
 ◇ " 20/80 " 30% "

Fig. 4

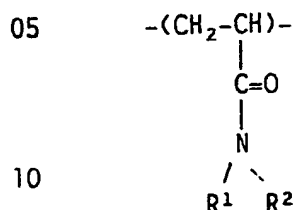
SOLID POLYACRYLAMIDE ELECTROLYTE

This invention relates to bulk ionically conductive polymeric materials; more particularly, this invention relates to solid, non-crystalline polymer electrolytes possessing both high bulk ionic conductivity and good mechanical strength and toughness, and to their use as ionic electrolytes in electrical devices such as galvanic cells and electrochromic displays.

Ionically conducting polymer electrolytes generally consist of a polymer and an inorganic electrolyte; the polymer should contain electronegative atoms and be capable of dissolving and complexing the inorganic electrolyte. Many polymers can be expected to exhibit these characteristics but in practice, systems based on polyethylene oxide (PEO) are most often found both commercially and in the literature for example Duval et al, paper EC11 of the European Symposium on Polymeric Materials, first meeting of the European Polymers Federation at Lyon, 14-18 September 1987. Ideally, the polymer should have a low degree of crystallinity because ionic conductivity occurs preferentially through the non-crystalline regions of the polymer, and it should also be a solid. With linear PEO, the characteristics of solidity and a low degree of crystallinity are mutually exclusive (only very low molecular weight liquid or waxy materials are non-crystalline or exhibit a low degree of crystallinity); the crystalline content of PEO can be reduced to some extent by virtue of complexing an inorganic electrolyte, but generally, the propensity to crystallise can otherwise only be prevented by modifying the polymer.


Examples of modified PEO may be found in the prior art; typical examples include comb-polymers such as poly(alkoxy-PEO-methacrylate)s and poly(alkoxy-PEO-siloxane)s in which linear PEO chains are attached as the teeth on the comb to an olefinic chain backbone or a siloxane chain backbone respectively. These materials are rubbery in the former case and are liquids in the latter.

According to the present invention, an ionically conducting solid polymer electrolyte comprises a complex of homopolymerised or copolymerised N,N-disubstituted acrylamide



with a monovalent alkali metal salt (hereinafter "the inorganic electrolyte") where  $\text{R}^1$  and  $\text{R}^2$  are alkyl, alkenyl, cycloalkyl, 15 cycloalkylene, aryl (all of which may be optionally substituted e.g., by methyl (non-complexing) or methoxy (complexing)) or where  $\text{R}^1-\text{N}-\text{R}^2$  form a ring e.g., piperidyl (non-complexing) or morpholinyl (complexing). The poly(N,N-disubstituted acrylamide) referred to as "the polymer" in this disclosure, may be 20 cross-linked by the incorporation of units derived from a polyfunctional monomer such as methylene-bis-acrylamide. The polymer may be plasticized by the presence of a low molecular weight compound such as an N,N-disubstituted amide or a nitrile or an oligoether. Thus additional tertiary amide groups may be 25 present in the form of added N,N-disubstituted acylamide, such as N,N-dimethylacetamide, nitrile groups may be present in the form of added acetonitrile, and ether groups may be present in the form of added oligo-ethylene oxide. The polymer may also be blended with one or more other polymers such as other members of 30 the family of poly(N,N-disubstituted acrylamide)s, or with PEO or PEO-related materials or other polymeric materials. Thus, additional ether groups may be present in the form of added polyethylene oxide.

The monovalent alkali metal cation may be lithium or sodium or potassium and the anion may be perchlorate or trifluoromethanesulphonate or another anion that is bulky or is a weak conjugate base.

- 05 The advantages of using poly(N,N-disubstituted acrylamide)s, in contrast to PEO-based materials, as the matrix in which an inorganic electrolyte is dissolved, are that these polymers possess superior thermal and chemical stability, form tough solids, are colourless and transparent, and are fully  
10 non-crystalline.
- 

- The polymer may be prepared by polymerisation, in solution or in bulk, of N,N-disubstituted acrylamides, referred to as "the monomer" in this disclosure, by thermally activated or photo-activated radically initiated polymerisation. The polymer  
15 may be obtained by homo-polymerisation of a single monomer or by co-polymerisation of two or more monomers. Polymers may also be blended.

- Copolymerisation of two or more monomers leads to copolymers having properties that may combine the better and desirable  
20 qualities of the parent homopolymers, and evidence of these benefits will be demonstrated later.

- Blending of several polymers does not necessarily lead to an enhancement of individual properties, but the process nevertheless provides a simple method for bringing together  
25 polymers where copolymerisation is inappropriate due to wide differences in the relative reactivities of selected co-monomers. Blending of polymers is furthermore appropriate when it is not convenient or possible to obtain them by a single synthetic route. An example would be the case of incorporating  
30 poly(N,N-disubstituted acrylamide)s conveniently prepared by radically initiated polymerisation with PEO prepared by anionically initiated polymerisation. The blended polymers may be either miscible or immiscible, though it is preferred that the several polymers are miscible and form an homogeneous blend with no visible phase separation. It is further preferred that the several polymers dissolve and complex



the inorganic electrolyte. Blending may also be used to bring together the complex with dispersed additives such as fillers and/or anti-oxidants designed to contribute to the overall properties. Blending may be achieved by melt extruding or  
05 solvent casting the complex with the additives.

In photo-initiated bulk polymerisation, an Me/D high pressure mercury discharge lamp may be used to provide a source of ultra violet (UV) light of wavelengths ranging from about 240 to about 380 nanometres (nm). With such a light source polymerisation may  
10 be conducted in thin walled glass vessels. However, glass is opaque to UV light below about 350nm so it is preferable to use vessels made from polyethylene which is less opaque to UV light. For example, with such a light source and with polyethylene vials a suitable arrangement for polymerisation is that the vials  
15 containing the monomer are placed in the plane of the light path at the circumference of a rotating disc (diameter 15cm, 6 rpm) such that they periodically pass at a distance of 10cm to 35cm, preferably 20cm to 35cm from the light source, or are held static at a distance of 10cm to 80cm, preferably 30cm to 50cm, most  
20 preferably 35cm to 45cm from the light source. Photo-initiated polymerisation is particularly useful for in situ generation of the polymer, for example in forming a thin polymer film at the surface of an electrode.

In solution polymerisation, it has been found convenient to  
25 use a monomer to solvent ratio (by weight) of less than 20%.

In polymers that are cross-linked the weight percentage of cross-linking monomer (e.g., methylene-bis-acrylamide) is preferably up to 30%, more preferably 15% to 25% on the weight of monomer.

30 The cation used in the formation of the complex incorporating the polymers of this invention is preferably lithium, sodium or potassium. Lithium is most preferred by reason of the current availability of electrode materials. The anion (counterion) is  
35 preferably large in order to reduce gross segregation in use, and

it is further preferred that the anion is a weak conjugate base.

Examples include:

- (i) monovalent anions derived from higher halogens, (e.g.  $\text{Br}^-$  and  $\text{I}^-$ ), (ii) complex monovalent anions, (e.g.,  $\text{SCN}^-$ ,  $\text{ClO}_4^-$ ,  $\text{HgI}_3^-$ ,  $\text{BF}_4^-$ ), (iii) carboxylic anions, preferably perfluorinated, (e.g.  $\text{C}_m\text{F}_{2m+1}\text{CO}_2^-$  such as  $\text{CF}_3\text{CO}_2^-$ ,  $\text{C}_2\text{F}_7\text{CO}_2^-$ ), (iv) sulphonic anions, preferably perfluorinated (e.g.,  $\text{C}_m\text{F}_{2m+1}\text{SO}_3^-$ ), where m is an integer from 1 to 6, preferably from 1 to 3.

Formation of the polymer-inorganic electrolyte complex, hereinafter called "the complex" may be achieved in a number of ways, for example dissolution of pre-formed polymer and inorganic electrolyte in a suitable solvent followed by evaporation of the solvent in a vacuum. With the polymers and inorganic electrolytes described in this invention methanol is suitable, and the solvent is removed by evaporation in a vacuum to yield the complex. The disadvantage of this process is that polymers that are cross-linked, either by design or because of the presence of polyfunctional monomeric impurities in the supplied monomer, are at best difficult to dissolve or form only swollen gels. An alternative method which avoids this disadvantage is to bring together the monomer and inorganic electrolyte prior to polymerisation.

Thus, the inorganic electrolyte may be dissolved directly in the monomer, or to assist rapid dissolution, in the presence of a suitable co-solvent for monomer and inorganic electrolyte, for which purpose N,N-dimethylacetamide or acetonitrile is suitable. The solvent is removed from the monomer prior to bulk polymerisation or from the polymer subsequent to solution polymerisation. The complexes so formed are usually colourless and transparent.

Removal of the last traces of solvent is extremely difficult. These solvent residues can act to plasticize the polymer and enhance the ionic conductivity of the complexes

without necessarily causing an undue loss in the solid nature of the complexes. This feature can be used to advantage.

Thus, a plasticizer may be any non-aqueous solvent, preferably one that will complex both the inorganic electrolyte and dissolve the polymer, such as N,N-dimethylacetamide, acetamide, formamide or acetonitrile, or it may be monomer such as N,N-dimethylacrylamide purposely added or from incomplete conversion during polymerisation, or it may be a low molecular weight polymer such as a polyether-based compound.

It is useful to distinguish between external and internal plasticizers, the distinction being that the former are not covalently linked to the polymer whereas the latter are covalently linked to the polymer.

Thus, copolymerisation may be used to generate polymers containing an "internal" plasticizer as part of the polymeric chain. For example, N,N-dibutylacrylamide may be used as an internal plasticizer in the copolymer obtained from N,N-dimethylacrylamide and N,N-dibutylacrylamide, in sufficient quantity to plasticize the copolymer adequately without however leading to undue loss in the solid nature of the polymer.

The ideal external plasticizer has a high dielectric constant, low viscosity, is stable, and is wholly compatible with the other co-components of the complex system. Combinations of plasticizers may be used.

Combinations of plasticizers could include non-complexing plasticizers such as non-polar organic solvents (e.g. hexane). It is preferred that the non-complexing plasticizer is miscible with the complexing plasticizer and it is further preferred that the proportion of non-complexing plasticizer incorporated in the combined plasticizers is such that the inorganic electrolyte is not precipitated.

In addition to the type and content of plasticizer, the method of preparation has been found to influence the bulk ionic conductivity of the complex. Thus, polymers prepared by thermally activated radically initiated bulk polymerisation usually exhibit lower stiffness or viscosity compared to the polymers prepared by photo-activated radically initiated bulk polymerisation. Furthermore, the complexes incorporating the polymers prepared by the former method exhibit ionic conductivities superior to those complexes incorporating polymers of identical chemical composition but prepared by the latter method. It has further been observed that polymers prepared by photo-activated radically initiated polymerisation yield complexes having superior ionic conductivities if the polymer is prepared in a glass rather than a polyethylene vessel.

Thus, bulk ionic conductivities greater than  $10^{-6}$  S/cm ( $S = \text{ohm}^{-1}$ ) at  $20^{\circ}\text{C}$  can be obtained in the case of complexes incorporating polymers, particularly poly(N,N-dimethylacrylamide) from commercial sources. Complexes incorporating polymers prepared photochemically in glass vessels and also incorporating plasticizers such as N,N-dimethylacetamide have been found to exhibit bulk ionic conductivities greater than  $10^{-4}$  S/cm at  $20^{\circ}\text{C}$  with polymer to plasticizer ratios of 70/30 by weight. Further increase in the bulk ionic conductivity, at least to greater than  $10^{-3}$  S/cm is possible with higher plasticizer content, but increasing the weight ratio of plasticizer to polymer above 60/40 leads to materials of inadequate rigidity unless the polymer is cross-linked.

In polymers that are cross-linked, the incorporated content of plasticizer can be higher than in the non-cross-linked polymer. It has been found that increasing the weight fraction of cross-linking monomer (i.e., increasing the cross-link density) allows higher levels of plasticizer to be incorporated,

but too high a cross-link density leads to materials that are friable, irrespective of the content of plasticizer. In practice, it has been found that levels of up to 80% plasticizer (on the weight of polymer) can be incorporated in polymer containing up to 30% of cross linking monomer on the weight of monofunctional monomer.

The concentration of inorganic electrolyte in the polymer matrix is most conveniently expressed by the ratio of complexing atoms in the polymer to monovalent cations derived from the inorganic electrolyte. In the polymers disclosed in this invention, the complexing groups are amide groups, and the preferred ratio of amide groups (expressed for simplicity as amide nitrogen atoms) to monovalent cation is 10 to 30, more preferably 12 to 18. Expressing the ratio in this way is not intended to imply that the cation is complexed wholly or partly with the nitrogen atom. The presence of co-N,N-disubstituted acrylamides, or N,N-disubstituted acrylamides as an external plasticizer provides additional amide groups, and in these cases it is preferred to express the ratio of combined tertiary amide nitrogen atoms to cations. In cases where there are two or more kinds of complexing atoms, for example with the presence of primary or secondary amides, nitriles or polyethers, the preferred ratio will be modified according to the nature of the complexes formed with the other kind of complexing atom or atoms.

The ionic conductivities of the complex were measured by a.c. impedance spectroscopy. In this method, the samples were pressed between brass or other electrodes and conductivity measurements were carried out using a 1172 Solartron frequency response analyser. The complex admittance was measured as a function of frequency from  $10^{-1}$  to  $6 \times 10^4$  Hz. Due to the blocking nature of the electrodes, the real part of the admittance rose with increasing frequency to a frequency-independent plateau. The value at the plateau was used to calculate the bulk ionic conductivity.

A variety of materials having a wide range of mechanical properties can be obtained with the polymers of this invention. Thus, it is possible to prepare polymeric materials that range from being tough, stiff solids to viscous resins. A feature of  
05 this diversity is that the materials can be tailored to have mechanical characteristics suitable for a variety of products and end uses.

The invention will now be described by way of example and with reference to the accompanying drawings, which show results  
10 from relevant materials (Fig 1 = Example 2; Fig 2 = Example 3; Fig 3 = Example 4; and Fig 4 = Example 5).

Example 1

Poly(N,N-dimethylacrylamide) was obtained from Polysciences (Cat 4590) and was a tacky off-white solid. The polymer was  
15 dissolved in anhydrous methanol (taking several days to form a clear liquor that contained insoluble material). The liquor was filtered and lithium perchlorate was added to the filtrate giving a ratio of N:Li of about 12. A disc of the polymer/electrolyte was obtained by repeating the processes of (1) adding a small  
20 quantity of the liquor to a brass disc conductivity cell and (2) evaporating the solvent off at 40°C under a flow of nitrogen, until a thickness of at least 1mm had been achieved (the process took three days).

Examination of the disc revealed a number of entrapped air  
25 bubbles and a concave exposed surface. In order to obtain a flat exposed surface, and thereby parallel faces, the sample was machined on a lathe. The sample was subjected to 16 hours in vacuo at 40°C to remove traces of anhydrous methanol and to minimise absorption of water before conductivity measurements  
30 were made, and the top electrode was fitted after the machined surface had been wetted with a little of the solution from which the discs had been prepared.

The conductivity of a disc of the solid polymer/electrolyte having a diameter of 16mm and thickness of 0.45mm ranged from  $2.8 \times 10^{-6}$  S/cm at 17°C to  $9.8 \times 10^{-5}$  S/cm at 110°C ( $S = \text{ohm}^{-1}$ )

Example 2

05     Lithium perchlorate was dissolved in a 50/50 w/w solution of N,N-dimethylacrylamide and N,N-dimethylacetamide, and the solution was placed in a soda glass cell (wall thickness 0.6mm, diameter 12.5mm, capacity 5mL) containing brass electrodes at the circumference of a rotating disc (6 rpm) such that the distance  
10     of the sample from the light source was from 15cm to 30cm. Polymerisation was initiated with methylbenzoylformate (0.02%) by 365nm UV.

15     The conductivity of the resultant transparent gel having inter-electrode dimensions of 10mm x 10mm x 10mm, and a nitrogen to lithium ratio of 12, was  $3.43 \times 10^{-4}$  S/cm at 20°C. Conductivities of related materials (acrylamide/acetamide ratio varied) at various temperatures are shown in Figure 1.

Example 3

20     Lithium perchlorate was dissolved in a 40/60 w/w solution of N,N-dimethylacrylamide and N,N-dimethylacetamide, and the solution was placed in a polyethylene vial (wall thickness 0.8mm, diameter 12.5mm, capacity 3mL) held 40cm from the light source. Polymerisation was initiated with methylbenzoylformate (0.02%) by 365nm ultra violet.

25     The conductivity of discs of the complex having a thickness of 3mm and nitrogen to lithium ratio of 12 was  $3.13 \times 10^{-4}$  S/cm at 20°C. Conductivities of related materials (acrylamide/acetamide ratio varied) at various temperatures are given in Figure 2.

30     Example 4

      The experiment described in example 3 is embodied in example 4 except that lithium trifluoromethanesulphonate was used as the inorganic electrolyte.

The conductivity of discs of the complex having a thickness of 3mm and nitrogen to lithium ratio of 12 was  $6.60 \times 10^{-4}$  S/cm at 20°C. Conductivities of related materials (acrylamide/acetamide ratio varied) at various temperatures are given in Figure 3.

Example 5

Lithium perchlorate was dissolved in a 40/60 w/w solution of (N,N-dimethylacrylamide and methylene-bis-acrylamide (90:10 w/w) and N,N-dimethylacetamide, and the solution was polymerised as described in Example 3.

The conductivity of discs of the complex having a thickness of 3mm and t-amide nitrogen to lithium ratio of 12 was  $3.6 \times 10^{-3}$  S/cm at 20°C. Conductivities of related materials (acrylamide/acetamide ratio varied and cross-linker content varied) at various temperatures are given in Figure 4.

Example 6

Lithium chloride was dissolved in N,N-dimethylacrylamide and the solution was placed in a vessel (capacity 5ml) containing brass electrodes. Polymerisation was initiated by azo-bis-methylpropionitrile (0.1%) at 60°C for 22.5 hours.

The conductivity of the resultant transparent gel having inter-electrode dimensions of 10mm x 10mm x 10mm, and a nitrogen to lithium ratio of 12, was  $1.75 \times 10^{-4}$  S/cm at 60°C.

Example 7

Lithium chloride was dissolved in a 90/10 w/w solution of N,N-dimethylacrylamide and N,N-dimethylacetamide and the solution was placed in a vessel containing brass electrodes. Polymerisation was initiated by azo-bis-methylpropionitrile (0.1%) at 60°C for 4 hours.

The conductivity of the resultant transparent gel having inter-electrode dimensions of 10mm x 10mm x 10mm, and a nitrogen to lithium ratio of 12, was  $3.02 \times 10^{-5}$  S/cm at 20°C.



Example 8

Lithium chloride was dissolved in a 50/50 w/w solution of N,N-dimethylacrylamide and N,N-dimethylacetamide and the solution was placed in a vessel containing brass electrodes. 05 Polymerisation was initiated by azo-bis-methylpropionitrile (0.02%) at 60°C for 24 hours.

The conductivity of the resultant transparent gel having inter-electrode dimensions of 10mm x 10mm x 10mm, and a nitrogen to lithium ratio of 12, ranged from  $1.89 \times 10^{-4}$  S/cm at 18°C to 10  $1.85 \times 10^{-3}$  S/cm at 63°C.

Example 9

Lithium perchlorate was dissolved in N,N-diethylacrylamide and methyl benzoyl formate (0.1% by weight on monomer) was added as initiator for the polymerisation. The mixture was polymerised 15 in a cell between two glass microscope cover slips of thickness 0.06mm using an inner wall to wall distance of 1mm. In stage (i) the sample was held 20cm. from the source for 30 min. and irradiated for 1 second in every 6 seconds; in stage (ii) it was held 10cm from the source for 30 min and irradiated 20 continuously; and in stage (iii) the sample was removed from the cell and held at a temperature of 80°C for 24 hrs under a pressure of 10mm Hg (1.3kPa).

The conductivity of the resulting transparent gel having an amide nitrogen:lithium ratio of 12 is given in Table I.

25 Example 10

Example 9 was repeated using lithium trifluoromethanesulphonate (Li triflate) instead of lithium perchlorate. Conductivities are given in Table I.

Example 11

30 Example 9 was repeated using N,N-dipropylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 12

Example 10 was repeated using N,N-dipropylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 13

05     Example 9 was repeated using N,N-di-n-butyl acrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 14

10     Example 10 was repeated using N,N-dibutylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 15

Example 9 was repeated using N,N-di-n-hexylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 16

15     Example 10 was repeated using N,N-di-n-hexylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 17

20     Example 9 was repeated using N-acryloylpiperidine instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 18

Example 10 was repeated using N-acryloylpiperidine instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 19

25     Example 9 was repeated using N-acryloylmorpholine instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 20

Example 10 was repeated using N-acryloylmorpholine instead of N,N-diethylacrylamide. Conductivities are given in Table I.

30     Example 21

Example 9 was repeated using N,N-dimethylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 22

Example 10 was repeated using N,N-dimethylacrylamide instead of N,N-diethylacrylamide. Conductivities are given in Table I.

Example 23

- 05      Example 21 was repeated except that dimethyl acetamide was added to the mixture in a quantity sufficient to give a ratio of N,N-dimethylacrylamide to dimethyl acetamide by weight of 90:10. Similar experiments were carried out with ratios 80:20, 70:30 and 60:40. In the case of the 60:40 ratio the final stage (iii) of
- 10      the polymerisation was carried out without application of reduced pressure. Conductivities of the products are given in Table II.

Example 24

- 15      Example 23 was repeated except that lithium perchlorate was replaced by lithium trifluoromethanesulphonate (Li triflate) and experiments were carried out at ratios 90:10, 80:20 and 70:30. Conductivities of the products are given in Table II.

TABLE I

Example	Salt	Temperature °C	Conductivity S cm <sup>-1</sup>
05	9 Li perchlorate	19.3	1.59 x 10 <sup>-8</sup>
	"	103.2	6.2 x 10 <sup>-5</sup>
	10 Li triflate	18.2	14.41 x 10 <sup>-8</sup>
	"	103.4	1.63 x 10 <sup>-5</sup>
10	"	139.6	3.46 x 10 <sup>-5</sup>
	11 Li perchlorate	51.5	1.59 x 10 <sup>-8</sup>
	"	140.5	6.6 x 10 <sup>-6</sup>
	12 Li triflate	51.7	6.13 x 10 <sup>-9</sup>
15	"	140.5	2.34 x 10 <sup>-6</sup>
	"	198.9	3.87 x 10 <sup>-6</sup>
	13 Li perchlorate	47.4	9.8 x 10 <sup>-9</sup>
	"	163.7	4.05 x 10 <sup>-6</sup>
20	14 Li triflate	47.4	3.93 x 10 <sup>-9</sup>
	"	164.4	1.3 x 10 <sup>-6</sup>
	"	191.6	2.52 x 10 <sup>-6</sup>
	15 Li perchlorate	47.4	3.5 x 10 <sup>-9</sup>
25	"	192.0	4.5 x 10 <sup>-7</sup>
	16 Li triflate	47.4	1.93 x 10 <sup>-9</sup>
	"	192.0	2.37 x 10 <sup>-7</sup>
	17 Li perchlorate	206.7	6.15 x 10 <sup>-8</sup>
30	18 Li triflate	205.5	3.99 x 10 <sup>-9</sup>
	19 Li perchlorate	192.1	2.88 x 10 <sup>-8</sup>
	20 Li triflate	186.2	2.21 x 10 <sup>-7</sup>
	21 Li perchlorate	51.5	2.18 x 10 <sup>-8</sup>
	"	159.1	3.21 x 10 <sup>-6</sup>
	22 Li triflate	51.5	1.05 x 10 <sup>-7</sup>
	"	159.1	2.9 x 10 <sup>-6</sup>
	"	198.9	4.45 x 10 <sup>-6</sup>

TABLE II

Example	Dimethyl acetamide, %	Salt	Temperature °C	Conductivity S cm <sup>-1</sup>
05	23	Li perchlorate	19.0	$1.56 \times 10^{-8}$
	"	"	117.5	$7.53 \times 10^{-5}$
	20	"	19.0	$1.23 \times 10^{-7}$
	"	"	117.5	$1.58 \times 10^{-4}$
	30	"	19.0	$7.82 \times 10^{-7}$
	"	"	117.5	$4.27 \times 10^{-4}$
10	40	"	19.0	$1.17 \times 10^{-6}$
	"	"	117.5	$5.83 \times 10^{-4}$
15	24	Li triflate	19.0	$3.38 \times 10^{-8}$
	"	"	118.2	$8.11 \times 10^{-5}$
	20	"	18.0	$2.24 \times 10^{-7}$
	"	"	118.2	$2.08 \times 10^{-4}$
	30	"	19.0	$1.44 \times 10^{-6}$
	"	"	118.2	$4.42 \times 10^{-4}$

CLAIMS

1. An ionically conducting solid polymer electrolyte, comprising a complex of homopolymerised or copolymerised N,N-disubstituted acrylamide



with a monovalent alkali metal salt, where R<sup>1</sup> and R<sup>2</sup> are independently alkyl, alkenyl, cycloalkyl, cycloalkylene or aryl, or R<sup>1</sup>-N-R<sup>2</sup> forms a ring.

2. An electrolyte according to Claim 1, wherein at least one of R<sup>1</sup> and R<sup>2</sup> is substituted.

3. An electrolyte according to Claim 2, wherein the substituent is methyl or methoxy.

4. An electrolyte according to any preceding claim, wherein the acrylamide is cross-linked by the incorporation of units derived from a polyfunctional monomer.

5. An electrolyte according to Claim 4, wherein said monomer is methylene-bis-acrylamide.

6. An electrolyte according to Claim 4 or 5, wherein the weight percentage of the polyfunctional monomer is up to 30% on the weight of the said acrylamide.

7. An electrolyte according to any preceding claim, wherein the polymer is plasticised by the presence of a low molecular weight compound.

8. An electrolyte according to Claim 7, wherein the low molecular weight compound is an N,N-disubstituted acylamide or a nitrile or an oligoether.

9. An electrolyte according to any preceding claim, wherein the polymer is blended with one or more other polymers.
10. An electrolyte according to Claim 9, wherein the blending polymer is another poly(N,N-disubstituted acrylamide) or  
05 polyethylene oxide.
11. An electrolyte according to any preceding claim, wherein the alkali metal is lithium.
12. An electrolyte according to any preceding claim, wherein the salt has a bulky anion or the anion is a weak conjugate base.
- 10 13. An electrolyte according to Claim 12, wherein the anion is perchlorate or trifluoromethanesulphonate.